

Supplementary Material

Physiological Performance and Biosorption Capacity of *Exiguobacterium* sp. SH31 Isolated from Poly-Extreme Salar de Huasco in the Chilean Altiplano: A study on Rare-Earth Element Tolerance

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1 Supplementary Tables

Table S1: Anova analysis and Tukey's test of EPS quantification by UV-Vis

Analysis of Variance Table								
Response: abs								
	Df	Sum Sq	Mean Sq	F value	Pr(>F)			
sample	4	0.0159323	0.0039831	36.632	6.046e-06 ***			
Residuals	10	0.0010873	0.0001087					

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1								
statistics								
MSerror		Df	Mean	CV	MSD			
0.0001087333		10	0.4236	2.461645	0.02802041			
\$parameters								
test name		t	ntr	StudentizedRange	alpha			
Tukey sample		5		4.654293	0.05			
\$means								
	abs		std r	Min	Max	Q25	Q50	Q75
control	0.4010000	0.007211103	3	0.395	0.409	0.3970	0.399	0.404
eu	0.4050000	0.005291503	3	0.401	0.411	0.4020	0.403	0.407
gd	0.4163333	0.015307950	3	0.407	0.434	0.4075	0.408	0.421
la	0.4076667	0.009018500	3	0.399	0.417	0.4030	0.407	0.412
sm	0.4880000	0.012165525	3	0.474	0.496	0.4840	0.494	0.495
\$comparison								
NULL								
\$groups								
abs groups								
sm	0.4880000	a						
gd	0.4163333	b						
la	0.4076667	b						
eu	0.4050000	b						
control	0.4010000	b						

Table S2: EPS quantification by UV-Vis.

Samples	Average	OD ₆₀₀	µg CR/OD ₆₀₀
Control	0.3427	1.102	0.3110
Sm	0.4297	1.098	0.3913
Eu	0.3467	1.096	0.3163
Gd	0.3581	1.100	0.3255
La	0.3494	1.084	0.3223

Table S3: % adsorption of REEs onto *Exiguobacterium* sp.

Samples	average adsorption %	%RSD
SH31 control La	0.00	0.00
SH31 0.1mM La	75.8	7.64
SH31 1mM La	93.3	3.61
SH31 control Sm	0.00	0.00
SH31 0.1mM Sm	80.6	22.6
SH31 1mM Sm	95.6	1.41
SH31 control Eu	0.00	0.00
SH31 0.1mM Eu	82.4	22.3
SH31 1mM Eu	96.8	0.47
SH31 control Gd	0.00	0.00
SH31 0.1mM Gd	76.1	17.9
SH31 1mM Gd	95.7	2.25

Table S4: % adsorption of REEs onto *Exiguobacterium* sp. at different pH values.

	pH7 - 0 g/L NaCl		pH7.5 - 0 g/L NaCl		pH8 - 0 g/L NaCl	
Samples	average adsorption %	%RSD	average adsorption %	%RSD	average adsorption %	%RSD
SH31 control La	0.00	0.00	0.00	0.00	0.00	0.00
SH31 0.1mM La	75.79	0.10	99.24	0.63	99.46	0.53
SH31 1mM La	93.31	0.04	99.62	0.17	99.64	0.10
SH31 control Sm	0.00	0.00	0.00	0.00	0.00	0.00
SH31 0.1mM Sm	80.62	0.28	99.31	0.67	99.47	0.43
SH31 1mM Sm	95.65	0.01	99.79	0.05	99.92	0.01
SH31 control Eu	0.00	0.00	0.00	0.00	0.00	0.00
SH31 0.1mM Eu	82.40	0.27	99.40	0.52	99.76	0.23
SH31 1mM Eu	96.79	0.00	99.83	0.07	92.42	5.25
SH31 control Gd	0.00	0.00	0.00	0.00	0.00	0.00
SH31 0.1mM Gd	76.15	0.24	99.37	0.65	95.84	3.62
SH31 1mM Gd	95.71	0.02	99.80	0.08	99.91	0.04

Table S5: Adsorption capacity of REEs onto *Exiguobacterium* sp. at different pH values and REE concentration.

	pH	qe (mg/g) La	%RSD	qe (mg/g) Sm	%RSD	qe (mg/g) Eu	%RSD	qe (mg/g) Gd	%RSD
0.1mM	7	1.7546	0.10	1.8292	0.31	1.8695	0.30	1.6897	0.28
0.1mM	7.5	2.2890	0.13	2.2910	0.15	2.2938	0.03	2.2905	0.28
0.1mM	8	1.6850	16.33	1.7767	2.15	2.0267	4.10	2.1611	0.42
1mM	7	21.6019	0.04	22.0587	0.02	22.3363	0.01	22.0263	0.03
1mM	7.5	23.0733	0.08	23.1042	0.02	23.1132	0.02	23.1067	0.01
1mM	8	20.9750	0.79	22.6317	0.42	22.9247	0.28	22.5567	0.26

Table S6: Calculated parameters of Langmuir isotherm

Metal concentration	pH	qm	Kl	Ce (µg/L)	slope	intercept	RL	qe	R ²
0.1 mM La	7	1.74	29.32	3.36	0.58	-0.02	0.01	1.72	1.00
	7.5			0.16			0.18	1.43	
	8			0.13			0.21	1.37	
1 mM La	7	21.53	33.42	9.29	0.05	0.00	0.004	1.73	1.00
	7.5			0.46			0.07	1.62	
	8			0.44			0.07	1.61	
0.1 mM Sm	7	1.81	37.93	2.92	0.55	-0.01	0.01	1.72	1.00
	7.5			0.14			0.19	1.40	
	8			0.11			0.24	1.32	
1 mM Sm	7	22.03	113.43	6.55	0.05	0.00	0.01	1.73	1.00
	7.5			0.28			0.11	1.55	
	8			0.10			0.25	1.31	
0.1 mM Eu	7	1.86	56.81	2.67	0.54	-0.01	0.01	1.71	1.00
	7.5			0.13			0.21	1.37	
	8			0.06			0.37	1.09	
1 mM Eu	7	22.26	46.24	4.88	0.04	0.00	0.01	1.72	1.00
	7.5			0.22			0.13	1.50	
	8			1.35			0.02	1.69	
0.1 mM Gd	7	1.65	8.33	3.75	0.61	-0.07	0.01	1.72	1.00
	7.5			0.15			0.19	1.41	
	8			0.92			0.04	1.67	

1 mM Gd	7	22.00	109.79	6.74	0.05	0.00	0.01	1.73	1.00
	7.5			0.26			0.12	1.54	
	8			0.12			0.22	1.35	

Table S7: Calculated parameters of Freundlich isotherm

Metal concentration	pH	KF	n	log q _e	log C _e	slope	intercept	1/n	C _e ^{1/n}	q _e	R ²
0.1 mM La	7	1.94	-11.94	0.24	0.53	-0.08	0.29	-0.08	0.90	1.76	1.00
	7.5			0.36	-0.81			-0.08	1.17	2.27	
	8			0.36	-0.90			-0.08	1.19	2.31	
1 mM La	7	22.7	-45.98	1.33	0.97	-0.02	1.36	-0.08	0.83	1.61	1.00
	7.5			1.36	-0.34			-0.08	1.07	2.07	
	8			1.36	-0.36			-0.08	1.07	2.08	
0.1 mM Sm	7	1.98	-14.00	0.26	0.46	-0.07	0.30	-0.08	0.91	1.78	
	7.5			0.36	-0.84			-0.08	1.18	2.29	
	8			0.36	-0.97			-0.08	1.21	2.34	
1 mM Sm	7	22.6	-81.68	1.34	0.82	-0.01	1.35	-0.08	0.85	1.66	0.96
	7.5			1.36	-0.56			-0.08	1.11	2.17	
	8			1.36	-0.98			-0.08	1.21	2.35	
0.1 mM Eu	7	1.99	-17.2	0.27	0.43	-0.06	0.30	-0.08	0.92	1.79	0.97
	7.5			0.36	-0.90			-0.08	1.19	2.31	
	8			0.36	-1.24			-0.08	1.27	2.47	
1 mM Eu	7	22.8	-94.2	1.35	0.69	-0.01	1.36	-0.08	0.88	1.70	0.86

	7.5			1.36	-0.66			-0.08	1.13	2.21	
	8			1.36	0.13			-0.08	0.98	1.89	
0.1 mM Gd	7	1.99	-11.0	0.23	0.57	-0.09	0.30	-0.08	0.90	1.74	0.83
	7.5			0.36	-0.83			-0.08	1.17	2.28	
	8			0.33	-0.03			-0.08	1.01	1.96	
1 mM Gd	7	22.6	-77.73	1.34	0.83	-0.01	1.35	-0.08	0.85	1.66	0.97
	7.5			1.36	-0.59			-0.08	1.12	2.18	
	8			1.36	-0.93			-0.08	1.20	2.32	

Table S8: Calculated parameters of Temkin isotherm

Metal concentration	pH	qe	ln Ce	slope	intercept	B	bt	Kt	R ²
0.1 mM La	7	1.75	1.21	-0.17	1.96	-0.17	-14465.26	0.00	1.00
	7.5	2.29	-1.86						
	8	2.29	-2.07						
1 mM La	7	21.6	2.23	-0.49	22.68	-0.49	-5018.23	0.00	1.00
	7.5	23.1	-0.78						
	8	23.1	-0.83						
0.1 mM Sm	7	1.83	1.07	-0.15	1.99	-0.15	-16622.56	0.00	1.00
	7.5	2.29	-1.94						
	8	2.30	-2.23						
1 mM Sm	7	22.06	1.88	-0.28	22.61	-0.28	-8813.72	0.00	0.96
	7.5	23.10	-1.29						

	8	23.13	-2.27						
0.1 mM Eu	7	1.87	0.98	-0.12	2.00	-0.12	-20178.05	0.00	0.97
	7.5	2.29	-2.06						
	8	2.31	-2.85						
1 mM Eu	7	22.34	1.59	-0.24	22.82	-0.24	-10099.83	0.00	0.86
	7.5	23.11	-1.51						
	8	22.92	0.30						
0.1 mM Gd	7	1.69	1.32	-0.18	2.01	-0.18	-13567.31	0.00	0.85
	7.5	2.29	-1.92						
	8	2.16	-0.08						
1 mM Gd	7	22.03	1.91	-0.29	22.60	-0.29	-8393.80	0.00	0.97
	7.5	23.11	-1.35						
	8	23.13	-2.13						

Table S9: Proteins of interest related to lanthanides metabolism identified in the genome of *Exiguobacterium* sp. SH31

Query	Uniprot	Genbank	Described function	Identity %	QC %
E_sp_SH31_00083	A0A4P9UL39	QCW80831.1	thymidylate synthase	63.54	100
E_sp_SH31_00515	A0A4P9URN0	QCW83011.1	phosphate ABC transporter ATP-binding protein	61.11	90.9
E_sp_SH31_00577	A0A4P9UP51	QCW81306.1	elongation factor 4	61.47	98.4
E_sp_SH31_00618	A0A2R5FBI7	GBG15610.1	isocitrate dehydrogenase	62.32	99.7
E_sp_SH31_00695	A0A4P9ULA6	QCW80911.1	methionine adenosyltransferase	61.42	98.1
E_sp_SH31_00808	A0A2R5FCJ9	GBG15942.1	ATP-dependent Clp protease, protease subunit	69.52	97.9
E_sp_SH31_01102	A0A4P9ULI7	QCW81977.1	glucose-1-phosphate thymidyltransferase	63.99	88.3
E_sp_SH31_01139	A0A4P9UPR5	QCW83404.1	UDP-glucose 4-epimerase GalE	62.32	99.7
E_sp_SH31_01275	A0A2R5FB49	GBG15255.1	glycine hydroxymethyltransferase	67.00	96.6
E_sp_SH31_01398	A0A4P9UTP3	QCW83086.1	tryptophan synthase subunit beta	63.73	97.9
E_sp_SH31_01486	A0A4P9UU39	QCW83921.1	alkylphosphonate utilization protein	71.68	100
E_sp_SH31_01652	A0A2R5F6U5	GBG13927.1	anthranilate synthase component II	61.70	96.9
E_sp_SH31_01720	A0A2R5F3B2	GBG12619.1	2-C-methyl-D-erythritol 2,4-cyclodiphosphate synthase	63.23	98.7
E_sp_SH31_01804	A0A2R5F2R9	GBG12479.1	Peroxioredoxin	68.28	99.5
E_sp_SH31_02227	A0A4Y9VUU0	TFW73423.1	5-(carboxyamino)imidazole ribonucleotide mutase	63.19	93.5
E_sp_SH31_02416	A0A2R5FEX4	GBG14944.1	aldehyde dehydrogenase	69.57	100
E_sp_SH31_02635	A0A4P9UPT4	QCW83424.1	ATP-dependent Clp protease ATP-binding subunit ClpX	63.29	93.6
E_sp_SH31_02960	A0A4Y9VN60	TFW69669.1	succinate--CoA ligase subunit alpha	64.97	96.4

Table S10: Descriptive statistics for EPS quantification by UV-Vis

<i>Control</i>			<i>Eu</i>			<i>Gd</i>		
Mean	0.34273288		Mean	0.34673288		Mean	0.35806621	
Standard Err	0.00416333		Standard Err	0.00305505		Standard Err	0.00883805	
Median	0.34073288		Median	0.34473288		Median	0.34973288	
Mode	#N/A		Mode	#N/A		Mode	#N/A	
Standard Dev	0.0072111		Standard Dev	0.0052915		Standard Dev	0.01530795	
Sample Vari	5.2E-05		Sample Vari	2.8E-05		Sample Vari	0.00023433	
Kurtosis	#DIV/0!		Kurtosis	#DIV/0!		Kurtosis	#DIV/0!	
Skewness	1.15206964		Skewness	1.45786297		Skewness	1.72373918	
Range	0.014		Range	0.01		Range	0.027	
Minimum	0.33673288		Minimum	0.34273288		Minimum	0.34873288	
Maximum	0.35073288		Maximum	0.35273288		Maximum	0.37573288	
Sum	1.02819864		Sum	1.04019864		Sum	1.07419864	
Count	3		Count	3		Count	3	
Confidence L	0.01791337	<0.05	Confidence L	0.01314482	<0.05	Confidence L	0.03802706	<0.05
<i>Sm</i>			<i>La</i>					
Mean	0.42973288		Mean	0.34939955				
Standard Err	0.00702377		Standard Err	0.00520683				
Median	0.43573288		Median	0.34873288				
Mode	#N/A		Mode	#N/A				
Standard Dev	0.01216553		Standard Dev	0.0090185				
Sample Vari	0.000148		Sample Vari	8.1333E-05				
Kurtosis	#DIV/0!		Kurtosis	#DIV/0!				
Skewness	-1.6795356		Skewness	0.33083181				
Range	0.022		Range	0.018				
Minimum	0.41573288		Minimum	0.34073288				
Maximum	0.43773288		Maximum	0.35873288				
Sum	1.28919864		Sum	1.04819864				
Count	3		Count	3				
Confidence L	0.03022084	<0.05	Confidence L	0.02240319	<0.05			

2. Supplementary Figures

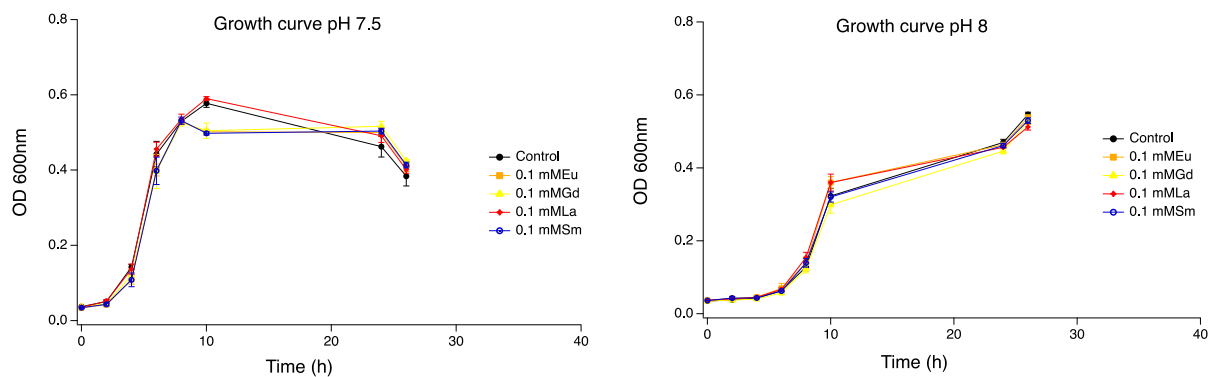


Figure S1: Growth curve of *Exiguobacterium* sp. at pH7.5 and 8 at 0.1mM of REEs. Error bars represent 3 independent replicates.

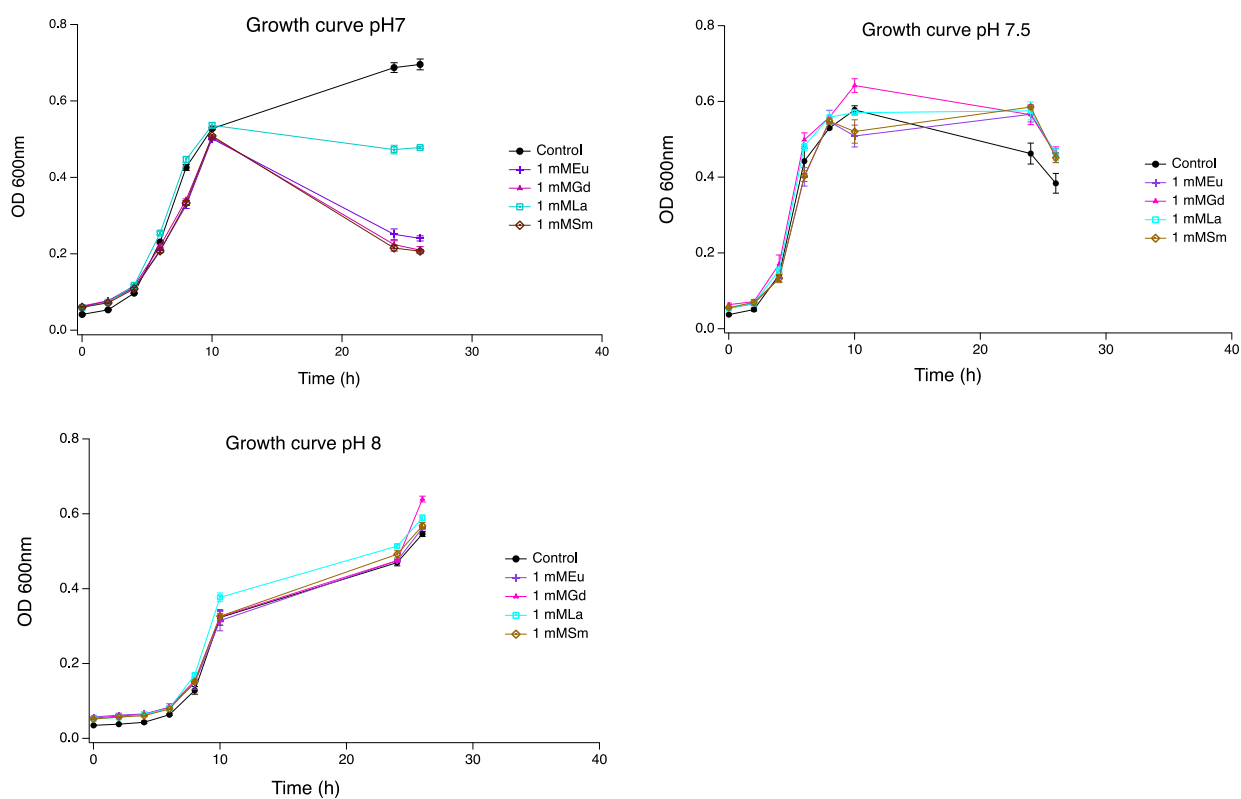


Figure S2: Growth curve of *Exiguobacterium* sp. at pH7, 7.5 and 8 at 1mM of REEs. Error bars represent 3 independent replicates.

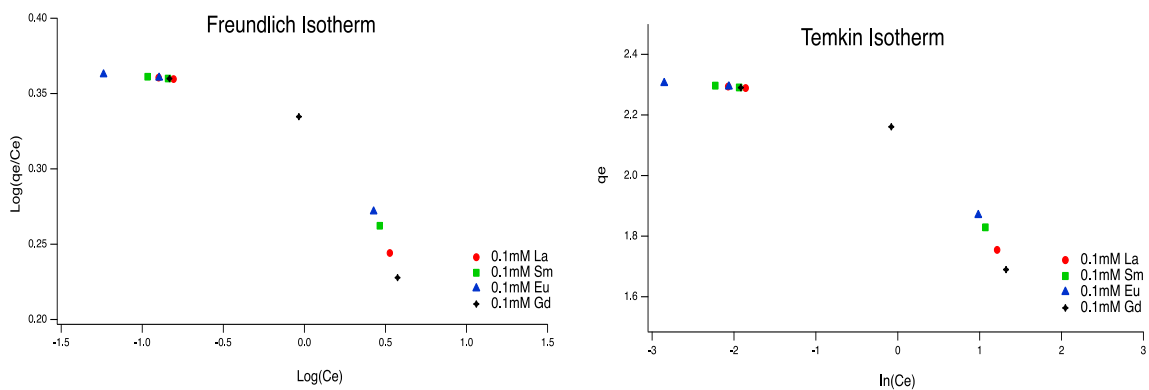


Figure S3: Freundlich and Temkin isotherms experimentally calculated for Rare-earth elements adsorption.